ISSN 1346-7565 Acta Phytotax. Geobot. 62 (1): 51–59 (2011)

# Contributions to the Moss Flora of Borneo, 1. A New Species, *Dimorphocladon echinocarpum* (Symphyodontaceae, Musci), with Unique Multicellular Exothecial Spines

HIROYUKI AKIYAMA

*Museum of Nature and Human Activities, Yayoigaoka-6, Sanda, Hyogo Prefecture 669-1546, Japan.*
*akiyama@hitohaku.jp*

*Dimorphocladon echinocarpum* H. Akiyama, with conspicuous multicellular spines on the exothecium, is described as new based on two specimens from northern East Kalimantan, Indonesia.

Key words: Borneo, bryophytes, *Dimorphocladon*, East Kalimantan, Kayan Mentarang National Park, new species, Symphyodontaceae

Northern Borneo is part of three countries; Malaysia (Sabah & Sarawak) and Brunei in the northwest and across the backbone range, and Indonesia (East Kalimantan) in the southeast. During the 20th century, bryological surveys were conducted mostly in the Malaysian and Brunei parts of Borneo, while East Kalimantan was left nearly untouched. Eastern part of East Kalimantan mostly consists of a vast range of lowland below 100 m and bryophyte diversity is very low because of low humidity. On the other hand, a large number of bryophytes are to expected in the western part of East Kalimantan, where elevations are much higher, especially near the border with Sabah and Sarawak.

A joint botanical survey was conducted in 1990 by Herbarium Bogoriense and the University of Tokyo to document plant diversity in the region, especially from Long Bawan to the peak of Gunung (Mt.) Batu Harun (2169 m alt.). Long Bawan is a small village at an elevation of 1000 m. It is situated near the border of the Malaysian state of Sabah, about a one week walk across lowland forests and river systems, or a one hour flight by a small plane, from the seaside city of Tarakan. Long Bawan is one of the main villages inside the Kayan Mentarang National Park and deeply involved in the WWF Heart of Borneo Initiative (Persoon & Osseweijer 2008). I joined the trips as a bryophyte specialist and collected more than 500 bryophyte specimens. In the course of identification, an interesting moss was found among the collections.

The moss was collected at 1000 m alt. near the camp site beside a small river at the foot of Batu Harum, a five-day hike through the forests from Long Bawan. It is characterized by geminate teeth on the leaf margins, linear laminal cells with distinct prorulae at the upper ends, weakly differentiated alar cells, a short, double costa, and sharply spinose capsules on smooth setae. In addition, a habitat preference for shrub leaves at rather sunny streamsides is also characteristic. These features suggest its close relationships to the Symphyodontaceae, especially *Dimorphocladon* Dixon or *Chaetomitrium* Dozy & Molk. Despite the superficial resemblance of the spines on the capsule walls to those of *Symphyodon* Mont., it is described here as a new species of *Dimorphocladon* as discussed below in detail.

**Dimorphocladon echinocarpum** H. Akiyama, **sp. nov.**—Figs. 1–11, 18–20.

Affine *Dimorphoclado borneensi* Dixon., sed capsulis ovoideis ad breviter cylindraceis, setis juxta capsulas argute flexis, et spinis in paginis capsularum multicellularibus diversum.

*Typus.* Indonesia, East Kalimantan, Kabupaten Bulungan, Kecamatan Long Bawan, north of Long Bawan village; in the vicinity of Bulu Kinuab, foot of Batu Harun, ca. 1070 m alt., 4°05′N, 115°50′E, 20 Sep. 1990, *H. Akiyama K-24208* (holo- HYO; iso- BO, L, NY).

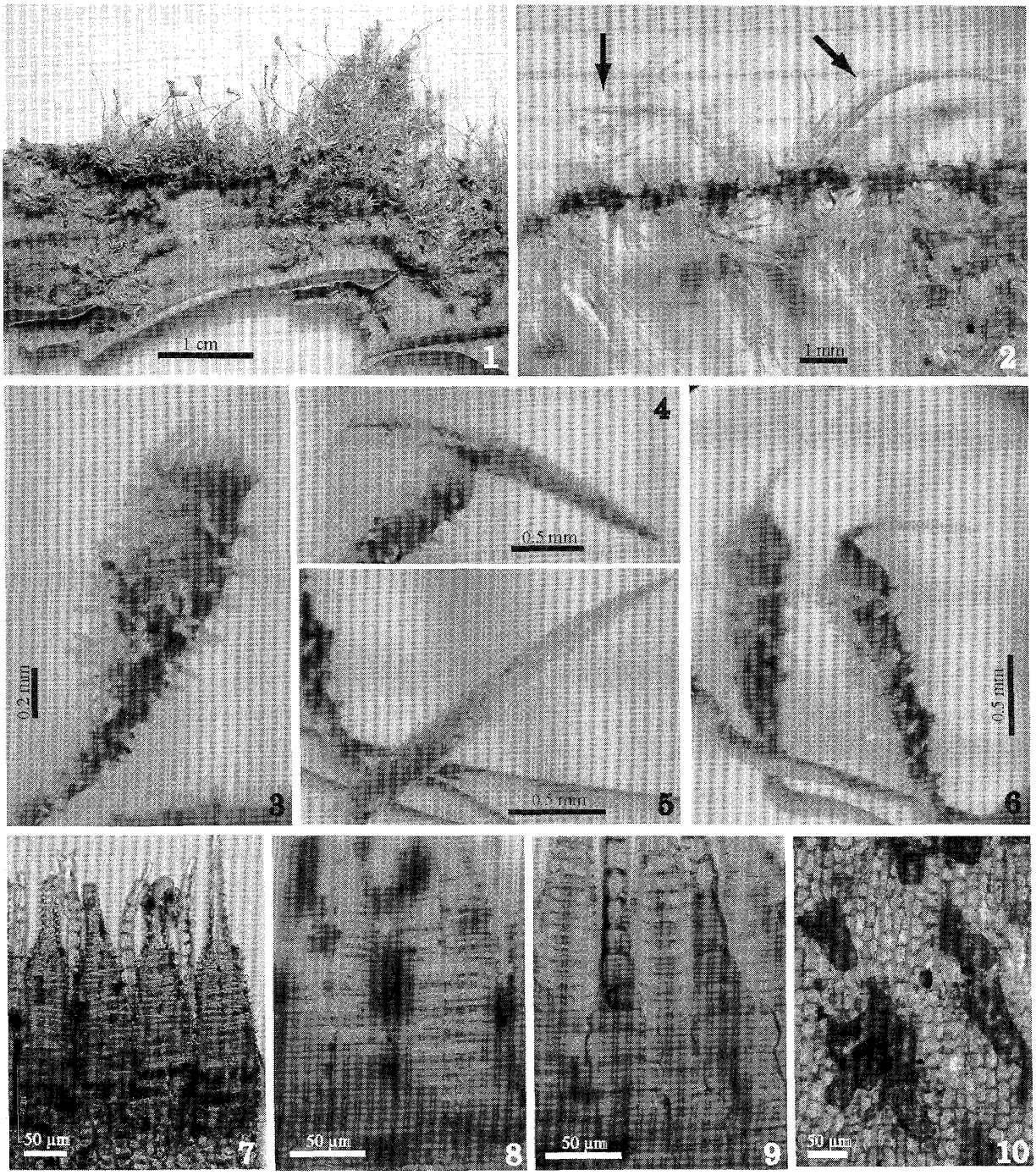


FIG. 1–10. *Dimorphocladon echinocarpum* (all from holotype). **1.** plants on leaf of living shrub. **2.** ventral side of prostrate stem showing disk-like rhizoid tufts (arrows indicate gemmiferous branches with filamentous gemmae in leaf axils). **3.** deoperculate capsule with closed peristomes in dry condition. **4.** echinate capsule with a cucullate, setose calyptra. **5.** closeup of young calyptra. **6.** densely echinate capsules and smooth opercula with long, slender beaks. **7.** outer surface of peristome. **8.** transversely striate ornamentation on lower portion of exostome teeth. **9.** inner surface of endostome with high basal membrane and keeled segments. **10.** exothecial cells with multicellular projections.

Plants green to olive-green in life, turning pale brownish yellow after drying, forming low, thin tufts on leaves of living shrubs. *Rhizoids* restricted to ventral surfaces of prostrate stems, tufted, smooth, brown. *Stems* pale green, becoming brownish yellow in age, prostrate, tightly attached to substrate by rhizoids, densely and pinnately branched; paraphyllia and pseudoparaphyllia absent; cortical cells lax, thin walled; epidermal cells thick walled, substereid, without central strand. *Branches* dimorphic. *Vegetative branches* mostly simple, usually less than 1 cm long, more or less complanately foliate. *Gemmiferous branches* similar to vegetative ones, but tapering apically, with a number of smooth walled, filamentous gemmae in leaf axils; gemmae 2–2.5 mm long. *Stem leaves* slightly smaller than branch leaves. Branch leaves narrowly lanceolate, 1.4–1.8 mm long, more or less shallowly concave, not decurrent at base, margins minutely revolute, apex long acuminate, twisted, with short but distinct geminate teeth throughout; costa double, reaching 1/3–1/4 of leaf length; upper laminal cells linear, ca. 100 $\mu$m long, becoming shorter apically, prorate on upper ends on dorsal surface, walls slightly thick ; median and lower laminal cells linear, walls slightly thick , 80–120 $\mu$m long, smooth; marginal laminal cells similar to inner ones but shorter; alar cells slightly differentiated, quadrate or hexagonal, ca. 3–5 in number, pale green, not porose. Axillary hairs hyaline, uniseriate, 2-celled; basal cell quadrate, pale brown; apical cell elongate, hyaline, smooth.

Autoicous. *Perigonia* on prostrate stems or at base of lateral branches, with ca. 10 antheridia and few paraphyses. *Perigonial leaves* ovoid, margins entire or finely serrulate distally, apex often laciniate, apiculate; costa double, 1/5 of leaf length. Perichaetia on prostrate stems or at base of lateral branches, with 3–10 archegonia, without paraphyses. Post-fertilization perichaetial leaves linear-triangular, 1.8–2.5 mm long, slightly concave, often laciniate distally, margins revolute and sharply serrulate, apex filamentous; costa weakly developed. *Calyptrae* cucullate, densely setose. Setae reddish brown, ca. 8 mm long, smooth, straight, but sharply bent and echinate just below neck of capsule. *Capsules* upright to horizontal, ovoid to short cylindrical, deep yellow, with short neck, 1–1.8 mm long, with multicellular spines 0.1–0.2 mm long throughout; exothecial cells quadrate to short rectangular, evenly thick walled, smooth; stomata absent; annuli present; opercula long rostrate, smooth, to 1 mm long; peristome double, brownish yellow, closed during dry conditions, exostome teeth 16, lanceolate below, dorsally with narrow median furrows, suddenly narrowed at shoulder into filamentous upper portion, to 450 $\mu$m in height, basally densely striate, margins more or less appendiculate, apically finely papillose; endostome to 450 $\mu$m in height, with high basal membrane, segments lanceolate, keeled, basally smooth, apically finely papillose; cilia rudimentary, 1 or absent. *Spores* ellipsoid, thin walled, longer axis 35–50 $\mu$m long, shorter axis 25–35 $\mu$m long.

*Additional specimen examined.* INDONESIA. Borneo Island. **East Kalimantan**: Kabupaten Bulungan, Kecamatan Long Bawan; in the vicinity of Tadur Bangar, 1050–1100 m alt., 04°15′N, 115°50′E, 20 Sep. 1990, *H. Akiyama K-24243* (HYO).

*Habitat.* On leaves of short shrubs at sides of streams in moist secondary and primary montane forests; quite similar to habitat of *Dimorphocladon borneense* and species of *Chaetomitrium.*

*Distribution.* Known only from the specimens cited above; probably endemic to northern Borneo.

*Distinguishing features.* (1) Epiphyllous on short shrubs at sides of streams in montane forests; (2) dimorphic branches with more or less complanate foliation; (3) filamentous gemmae in leaf axils of caudate, gemmiferous branches; (4) linear, slightly thick walled laminal cells; (5) low but distinct geminate teeth at leaf margins; (6) short, double costae; (7) weak differentiation of alar cells on branch leaves and with few quadrate to hexagonal cells; (8) smooth setae often sharply curved just below capsule; (9) capsules with multicellular spines and opercula with long, slender beak; (10) transversely striate ornamentation at base of exostome teeth; and (11) large, ellipsoid spores to 50 $\mu$m long in longer axis.

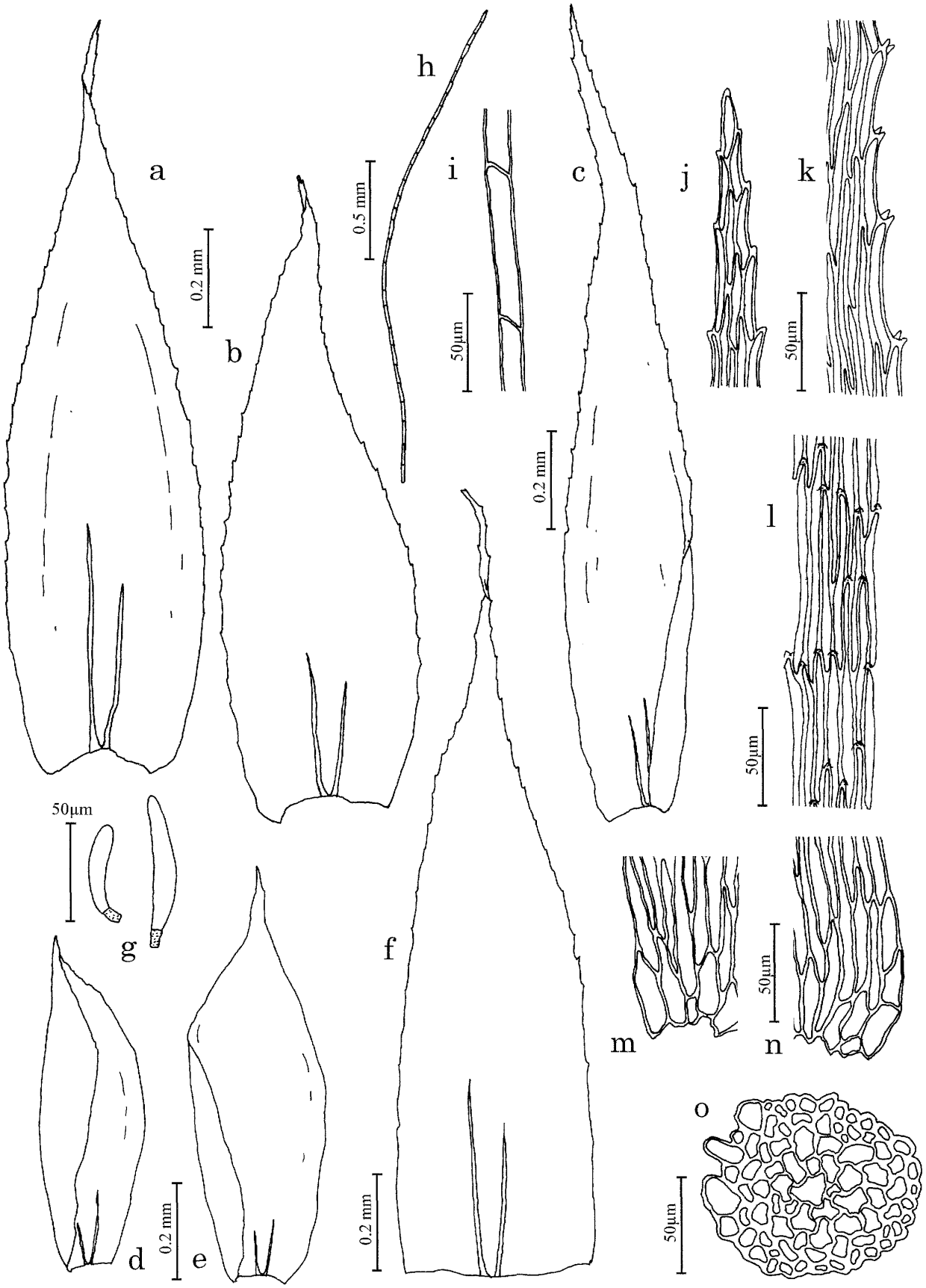


FIG. 11. *Dimorphocladon echinocarpum* (a–o: all from holotype). a & b: leaves of normal branches. c: a leaf of gemmiferous branch. d & e: perigonial leaves. f: a post-fertilization perichaetial leaf. h & i: filamentous gemmae in leaf axils. j: apex of branch leaf. k, apical margin of branch leaf. l: median laminal cells of branch leaf. m & n: alars of branch leaves. o, transverse section of branch.

*Comparison with* Dimorphocladon borneense (Figs. 12–17, 21–22)

*Dimorphocladon* was established as a monotypic genus by Dixon (1922) based on a single specimen collected in Sarawak in north central Borneo. The sole member, *D. borneense* Dixon, was then reported from the Malay Peninsula (Malaysia, Thailand; Dr. B. C. Tan, personal communication), the Philippines (Tan 1993), Seram (Akiyama 1997, 2009), and New Guinea (Schultze-Motel 1963). The species grows on the branches and living leaves of shrubs beside streams and small rivers in forests. According to my field observations, *D. borneense* is usually found in well preserved or secondary riparian thickets in lowlands and lower montane forests in southern and western Borneo.

*Dimorphocladon borneense* shares the following morphological features with *D. echinocarpum*; (1) dimorphic branches, (2) filamentous, smooth gemmae in leaf axils of gemmiferous branches, (3) geminate teeth to base of leaf margins, (4) linear, somewhat thick walled laminal cells with proration at upper end, (5) branch leaves with slightly differentiated, rectangular to quadrate alar cells, (6) double costa of 1/3–1/4 of leaf length, (7) opercula with long and slender beak, (8) non-collenchymatous exothecial cells smooth and thick walled, (9) striate ornamentation at base of exostome teeth, and (10) high basal membrane of endostome with keeled segments.

*Dimorphocladon borneense* differs from *D. echinocarpum* in the following features; (1) growing at lower elevations (100–800 m on the Malay Peninsula, Borneo and Seram; Akiyama 2009), (2) longer setae (15–20 mm long), (3) erect,

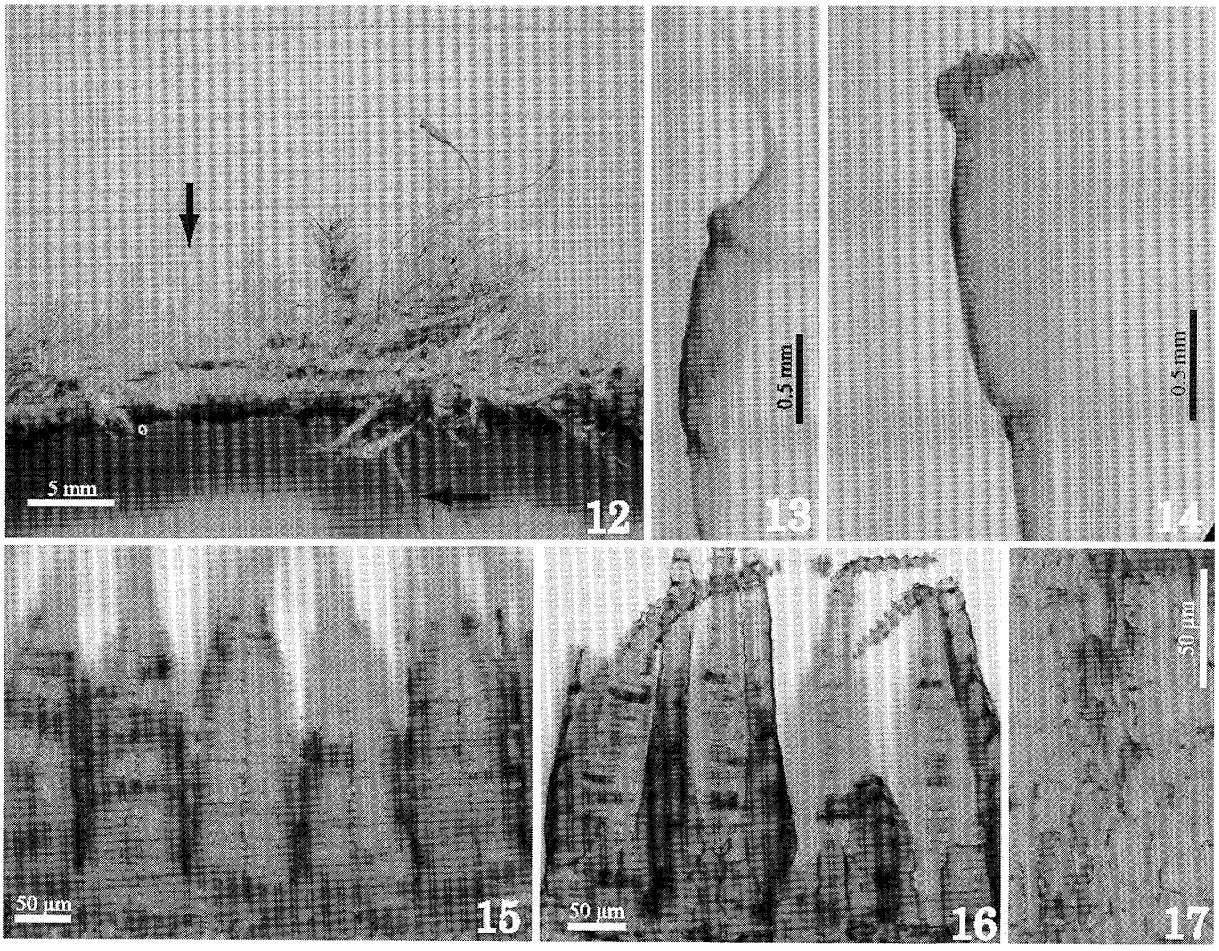


FIG. 12–17. *Dimorphocladon borneense* (*Akiyama Borneo-32447*). **12.** plants on branch of shrub (arrows indicate gemmiferous branches with filamentous gemmae in leaf axils). **13.** capsule with long slender operculum. **14.** deoperculate capsule. **15.** outer surface of exostome. **16.** inner surface of endostome with high basal membrane and keeled segments. **17.** exothecial cells.

cylindrical capsules, and (4) smooth walls of capsules with low, indistinct warts on neck. The low and indistinct warts (Figs. 21–22) are composed of several cells and thus might be rudimentary stage of the well developed spines of *D. echinocarpum*.

Dixon (1922) regarded the geminate teeth on the leaf margins of *Dimorphocladon borneense* to be an important feature for treating the genus as distinct from *Chaetomitrium*. Although species of *Symphyodon* do not have geminate teeth (He & Snider 2000), a number of species of *Chaetomitrium* do have them (Akiyama 1997, Akiyama & Suleiman 2001). Geminate teeth by themselves are not sufficient to distinguish *Dimorphocladon* from related genera.

*Specimens examined.* ***Dimorphocladon borneens.*** INDONESIA. Borneo. **West Kalimantan**: foot of Gunung Niut, 500 m alt., *H. Akiyama K-31440* (HYO); Putussibau, upper stream of Sungai Nuo, 160 m alt., *H. Akiyama K-32095* (HYO); ibid., upper reaches of Kapuas river, near Mata Lunai, 160 m alt. *H. Akiyama K-32477* (HYO). **South Kalimantan**: foot of Gunung Batu Besar, 400 m alt. *H. Akiyama K-24636* (HYO).

*Comparison to species of* Chaetomitrium *with echinate capsules and* Chaetomitriopsis glaucocarpa (Figs. 23–24)

More than 110 species of *Chaetomitrium* have been described, mostly from Southeast Asia. Among them, no less than 16 species have been reported from Borneo (Akiyama & Suleiman 2001, Suleiman *et al.* 2006). It is noteworthy that the 16 species are strictly confined to the branches and leaves of shrubs growing along streams in well preserved, lowland and lower montane forests, as are the species of *Dimorphocladon*. In addition, *Chaetomitrium* and *Dimorphocladon* share the following features; (1) filamentous gemmae in leaf axils, (2) proration at upper ends of laminal cells, (3) short, double costae (usually less than 1/3 of leaf length in *Chaetomitrium*), (4) leaf margins with geminate teeth, (5) weak differentiation of alar regions of branch leaves, (6) short, straight hairs on calyptra, (7) long, slender beak of opercula, (8) striate ornamentation on exostome teeth, and (9) larger spores (Mohamed & Robinson 1991). As for capsule posture, some are erect (e.g., *C. elegans* Geh., *C. torquescens* Bosch & Sande Lac.), but others are not (e.g., *C. perlaeve* Dixon) in *Chaetomitrium* and thus cannot be a separating feature.

It is also noteworthy that a few species of *Chaetomitrium* from New Guinea and nearby islands possess echinate capsules (e.g., *C. acanthocarpum* Bosch & Sande Lac.; Bartram 1961, Akiyama 1997). The spines on the capsules, however, are merely projections, each spine arising from a single exothecial cell (Figs. 23–24).

Among the most striking features separating *Chaetomitrium* from *Dimorphocladon* are the papillose, spinose, or sometimes warty setae (Fleischer 1908, Akiyama & Suleiman 2001). On this point, it should be noted that a single species, *Chaetomitriopsis glaucocarpa* (Reinw. ex Schwägr.) M. Fleisch., is separated from *Chaetomitrium* by the long, smooth setae (Akiyama 2006, Fleischer 1923, Mohamed & Robinson 1991). According to a recent molecular phylogenetic analysis (Ho 2010), *Chaetomitriopsis glaucocarpa* is an in-group member of *Chaetomitrium* with high bootstrap probability. The smooth setae, also found in *Dimorphocladon*, should therefore be treated as mere variation within *Chaetomitrium*. As a result, the relationships between *Dimorphocladon*, *Chaetomitrium* and *Chaetomitriopsis* M. Fleisch. remain ambiguous and are in need of further analysis.

*Specimens examined.* ***Chaetomitriopsis glaucocarpa.*** INDONESIA. Borneo. **East Kalimantan**: Long Bawan, Bulu Kinuab., 1070 m alt., *H. Akiyama K-24195* (HYO).

***Chaetomitrium acanthocarpum.*** INDONESIA. **Maluku.** Central Seram: Tehoru, from Hunisi to Wae Heka Heka, 350 m alt., *H. Akiyama C-15958* (HYO). —North Seram: near Elemata-Makualaina, 100–350 m alt., *H. Akiyama C-9313 & C-9372* (both HYO).

*Comparison to species of* Symphyodon (Figs. 25–26)

The genus *Symphyodon* is distributed in temperate to tropical zones worldwide. Two species, *S. perrottetii* Mont. and *S. copelandii* Broth., have been reported from Borneo. According to He & Snider (2000), the species of *Symphyodon* resemble *Dimorphocladon echinocarpum* in the

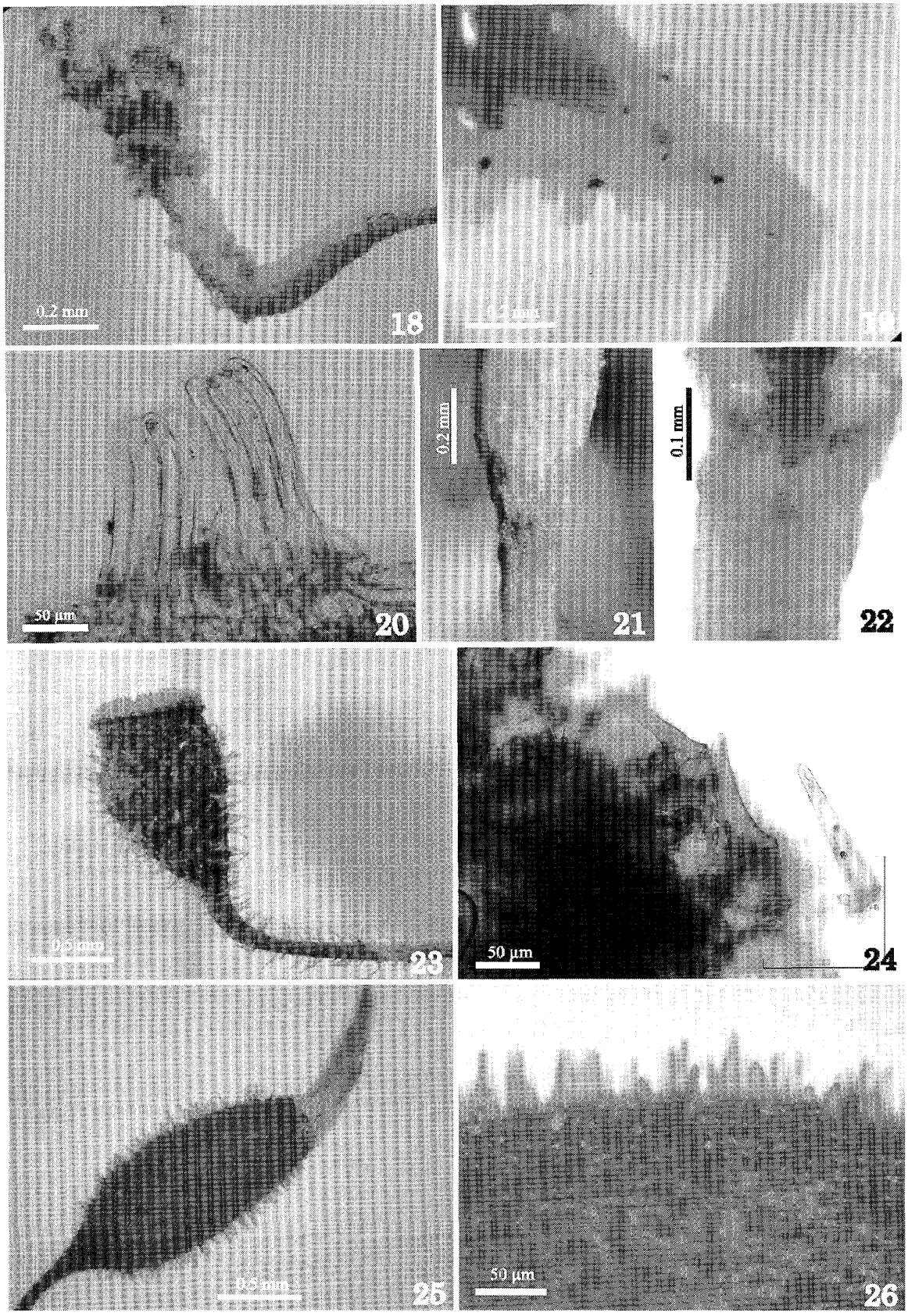


FIG. 18–26. Spines on capsules. *Dimorphocladon echinocarpum* (18–20; holotype), *D. borneense* (21–22; *Akiyama K-32477*, West Kalimantan), *Chaetomitrium acanthocarpum* (23–24; *Akiyama C-15958*, Seram Island) and *Symphyodon scaber* (Tixier) S. He & Snider (25–26; *H. Akiyama et al. 117*, Thailand, Doi Inthanon). **18** & **19.** closeup of neck of capsule and curved, roughly echinate uppermost portion of a seta. **20.** two multicellular spines with elongate cells on capsule walls. **21** & **22.** neck portion of capsules; note low, multicellular warts. **23** & **25.** deoperculate capsules. **24** & **26.** unicellular spines on capsule walls.

(1) proration of upper ends of linear laminal cells, (2) short, double costae, (3) weak differentiation of alar cells of branch leaves, (4) margins of leaves with distinctive serrations throughout, (5) smooth setae, (6) echinate to highly papillose capsule walls, and (7) epiphytic nature growing on branches of short shrubs and undergrowth. *Symphyodon* differs from *Dimorphocladon* in sporophytic features and habitat preference as follows; (1) exostome teeth linear-lanceolate, outer surface at base sparsely papillose, (2) endostome rudimentary, with low basal membranes and linear segments, (3) smaller spores ranging 13–20 $\mu$m in diameter, and (4) preferring somewhat shaded forest floors and edges of forests (He & Snider 2000). In addition, each spine on the capsule walls in *Symphyodon* is a mere projection from a single exothecial cell (Figs. 25–26), as in *Chaetomitrium acanthocarpum*, and differs considerably from the multicellular spines of *Dimorphocladon echinocarpum*. As shown in a molecular analysis (Ho 2010), these morphological differences also suggest a rather distant relationships between *Dimorphocladon* and *Symphyodon*.

As discussed above, the relationship of *Dimorphocladon echinocarpum* with other members of the Symphyodontaceae cannot be determined morphologically. Although tentatively classified under *Dimorphocladon*, molecular analyses are needed to settle its systematic position, especially in regard to *Chaetomitrium*.

*Dimorphocladon echinocarpum* and related species and genera all share the short, double costae, linear and more or less thick walled laminal cells with proration at the upper end, slight differentiation of alar cells, and double peristomes. They may be distinguished by the following key.

Keys to *Dimorphocladon echinocarpum* and related taxa

1a. Setae spinose, setose, or highly mammillose ..... *Chaetomitrium* spp.
1b. Setae smooth (often mammillose or papillose apically) ..... 2
2a. Capsules spinose or warty ..... 3
2b. Capsules smooth ..... 4
3a. Exostome teeth papillose at base; endostome with linear segments and low basal membrane; spines on capsules unicellular, a mere cuticle projection of cell wall ..... *Symphyodon* spp.
3b. Exostome teeth densely striate at base; endostome with lanceolate segments and high basal membrane; spine on capsules multicellular ..... *Dimorphocladon echinocarpum*
4a. Plants complanately foliate; filamentous gemmae present in leaf axils of gemmiferous branches; teeth of leaf margins geminate; setae to 20 mm long ..... *Dimorphocladon borneense*
4b. Plants roundly foliate, squarrose. Gemmae absent; teeth of leaf margins simple; setae to 40 mm long ..... *Chaetomitriopsis glaucocarpa*

I thank Dr. M. Kato (National Museum of Nature and Science, Tokyo) who offered me the chance to join the cooperative botanical expeditions to eastern, western, and southern Kalimantan held by University of Tokyo and Herbarium Bogoriense (Indonesian Institute of Sciences LIPI), Dr. W. R. Buck (New York Botanical Garden) for linguistic corrections, and Dr. H. Nagamasu (Kyoto University Museum) for his kind help in preparing the Latin diagnosis.

## References

Akiyama, H. 1997. Taxonomic studies of mosses of Seram and Ambon (Moluccas, East Malesia) collected by Indonesian-Japanese Botanical Expeditions VIII. Meteoriaceae, Hookeriaceae, and Trachypodaceae. Nature and Human Activities 2: 9–31.

Akiyama, H. 2006. New synonymy of *Chaetomitriopsis glaucocarpa* (Hypnaceae, Musci). Trop. Bryol. 28: 61.

Akiyama, H. 2009. Taxonomical studies of mosses of Seram and Ambon (Moluccas, East Malesia) collected by Indonesian-Japanese Botanical Expeditions, X. Bartramiaceae, Brachytheciaceae, Bryaceae, Ditrichaceae, Erpodiaceae, Hylocomiaceae, Hypnaceae (in part), Mniaceae, Orthotrichaceae, Regmatodontaceae, and Splachnaceae with corrections/additions to the previous reports. Humans and Nature 20: 15–28.

Akiyama, H. & M. Suleiman. 2001. Taxonomical notes on

the genus *Chaetomitrium* (Hookeriaceae, Musci) of Borneo. Hikobia 13: 491–509.

Bartram, E. B. 1961. Low altitude mosses from northeastern New Guinea. Brittonia 13: 368–380.

Dixon, H. N. 1922. Some new genera of mosses. J. Bot. 60: 101–110.

Fleischer, M. 1908. Die Musci der Flora von Buitenzorg, vol. 3. E. J. Brill, Leiden.

Fleischer, M. 1923. Die Musci der Flora von Buitenzorg, vol. 4. E. J. Brill, Leiden.

He, S. & J. A. Snider. 2000. A taxonomic revision of *Symphyodon* (Musci: Symphyodontaceae). Bryologist 103: 52–81.

Ho, B.-C. 2010. Evolution and Diversification of the Hookeriales (Bryopsida) with Emphasis on *Distichophyllum* (Daltoniaceae) and Its Allied Genera. Dissertation, Friedrich-Wilhelms-Universität, Bonn.

Mohamed, H. & H. Robinson. 1991. A taxonomic revision of the moss family Hookeriaceae and Hypopterygiaceae in Malaya. Smithsonian Contr. Bot. 80: 1–44 + i–iv.

Persoon, G. A. & M. Osseweijer. 2008. Reflections on the Heart of Borneo. Tropenbos International, Wageningen. (http://www.tropenbos.org/tbi_publications/documents/TBI_Series_24.pdf).

Schultz-Motel, W. 1963. Vorläufiges Verzeichnis der Laubmoose von Neuguinea. Willdenowia 3: 399–549.

Suleiman, M., H. Akiyama & B. C. Tan. 2006. A revised catalogue of mosses reported from Borneo. J. Hattori Botanical Lab. 99: 107–183.

Tan, B. C. 1993. Noteworthy range extension of Malesian mosses. J. Hattori Bot. Lab. 74: 227–233.

*Received April 5, 2011; accepted May 11, 2011*